

Beach Tar Accumulation at Coal Oil Point, CA: Distribution, Variation, and Possible Sources

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1. Abstract

The Coal Oil Point (COP) natural marine hydrocarbon seep field in the Santa Barbara Channel releases >100 barrels oil day⁻¹, some of which deposits as tar on local beaches. Oil and gas seep from and orient parallel to three E-W trending faulted anticlines. The three seep trends are ~0.5, ~1.5, and ~3 km offshore of COP. This natural and continuous "oil spill" presents an opportunity for studying the fate of petroleum in the ocean, thereby aiding coastal management, especially in sensitive habitat areas near seeps. Beach tar accumulation at COP was surveyed on 57 random days throughout 2005 along 12 transects separated by 20 m. Tar accumulations were determined in six different size classes yielding up to 8 kg/day over 19,000 m². This is less than ten percent of the tar that could originate from the seep field. The data shows a seasonal variation with mean summer tar accumulation one order of magnitude higher than mean winter accumulation. Time variations in tar distributions were compared to environmental factors and suggest that higher tar accumulations are related to lower speed winds, diminished offshore winds, low swell, and higher water temperatures. Emission variability, weathering and sinking of oil/tar, and storms may also have played a role in observed temporal and spatial variations. A winter tar anomaly of ~40 kg on February 27 may be related to unusually high rainfall in January and February of 2005.

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Oil Slick Heading for COP

2. Introduction

Figure 1 - Conceptual Model

Three stage model for oil transport from Monterey Fm reservoir to COP beaches:
(1) Seabed oil seepage from the reservoir;
(2) Gas-driven transport vertically through the water column;
(3) Advection horizontally along the air-sea interface to the beach.

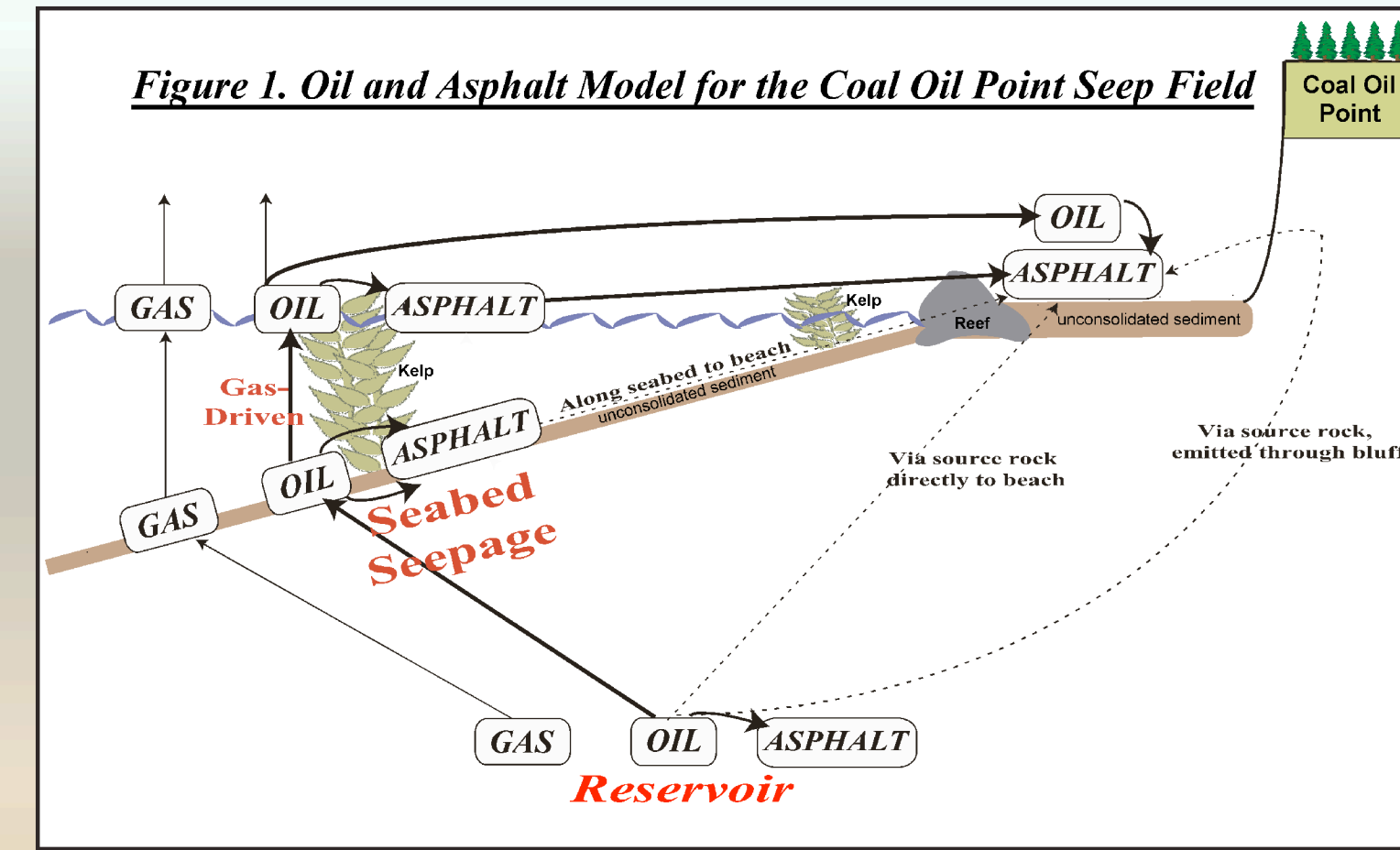
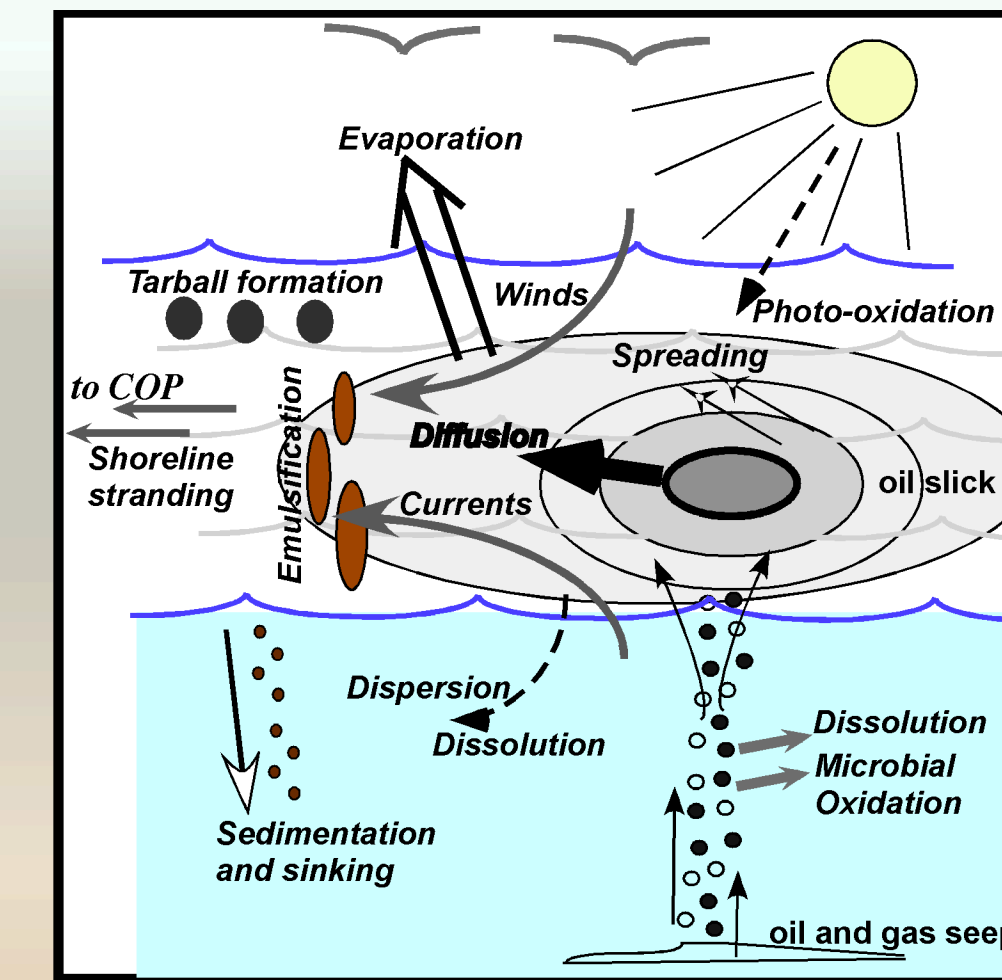


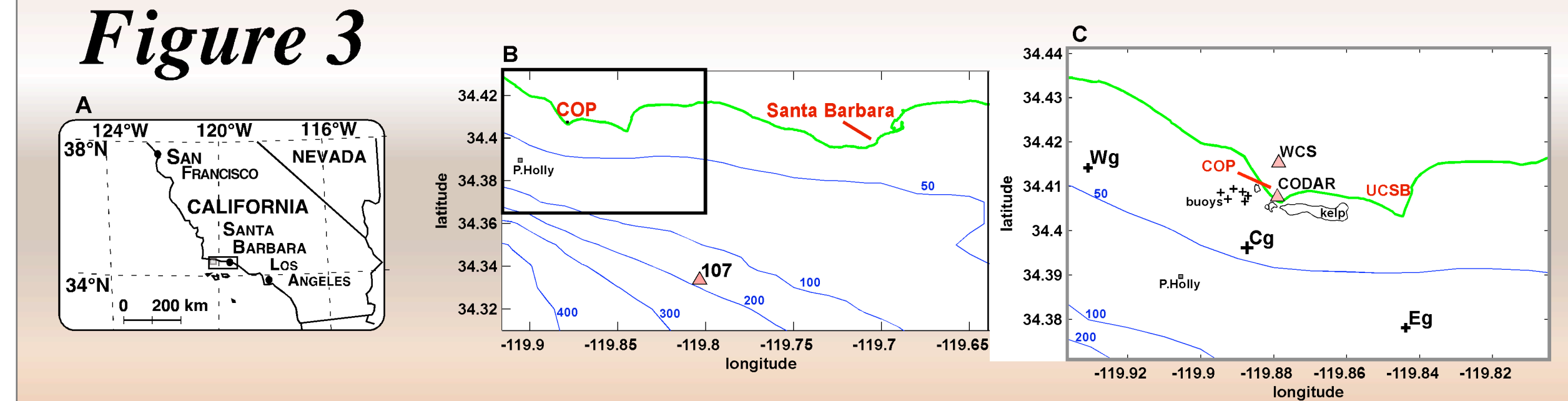
Figure 2. Oceanic Weathering and Transport of Oil



Throughout all stages, various transport and physical and chemical weathering processes are acting upon the oil. Weathering processes include evaporation, dissolution, photo and microbial-oxidation, emulsification, sedimentation and sinking, tarball formation and shoreline stranding. Oil is transported by dispersion, diffusion, spreading, and advection, via winds, currents, and tides.

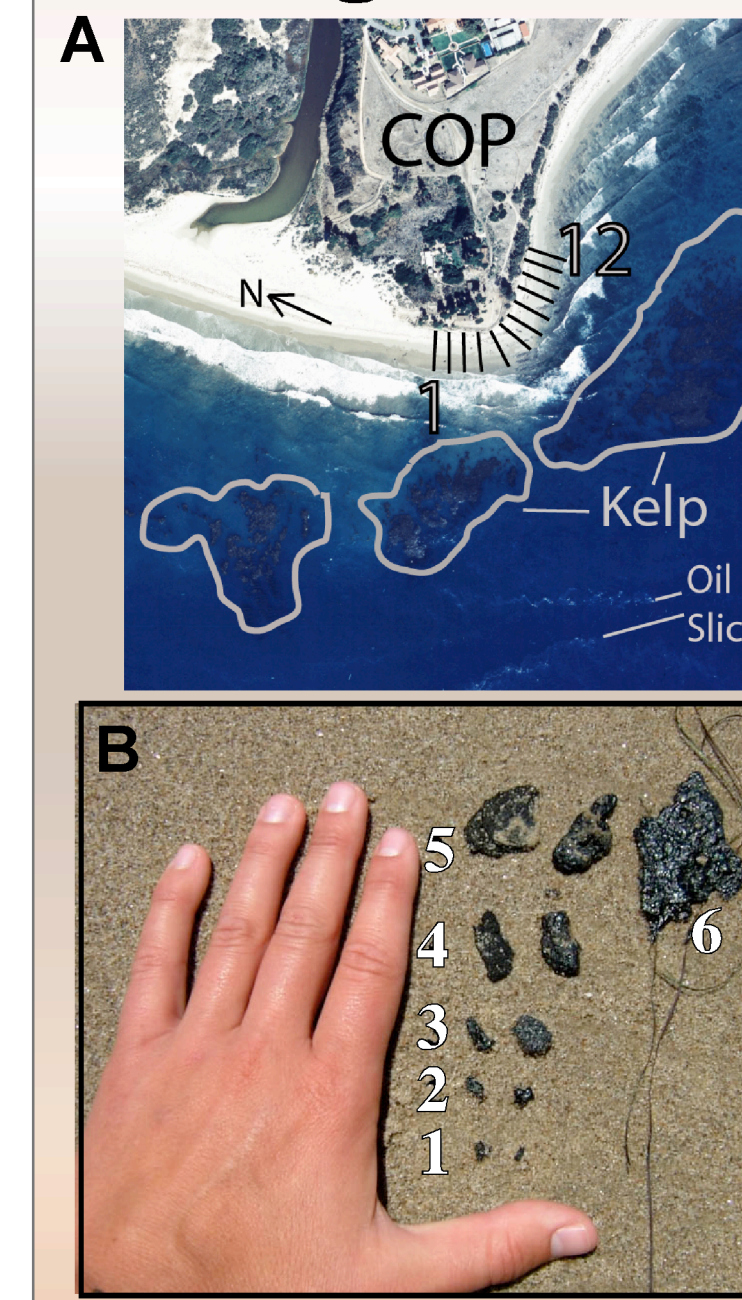
3. Methods

Figure 3



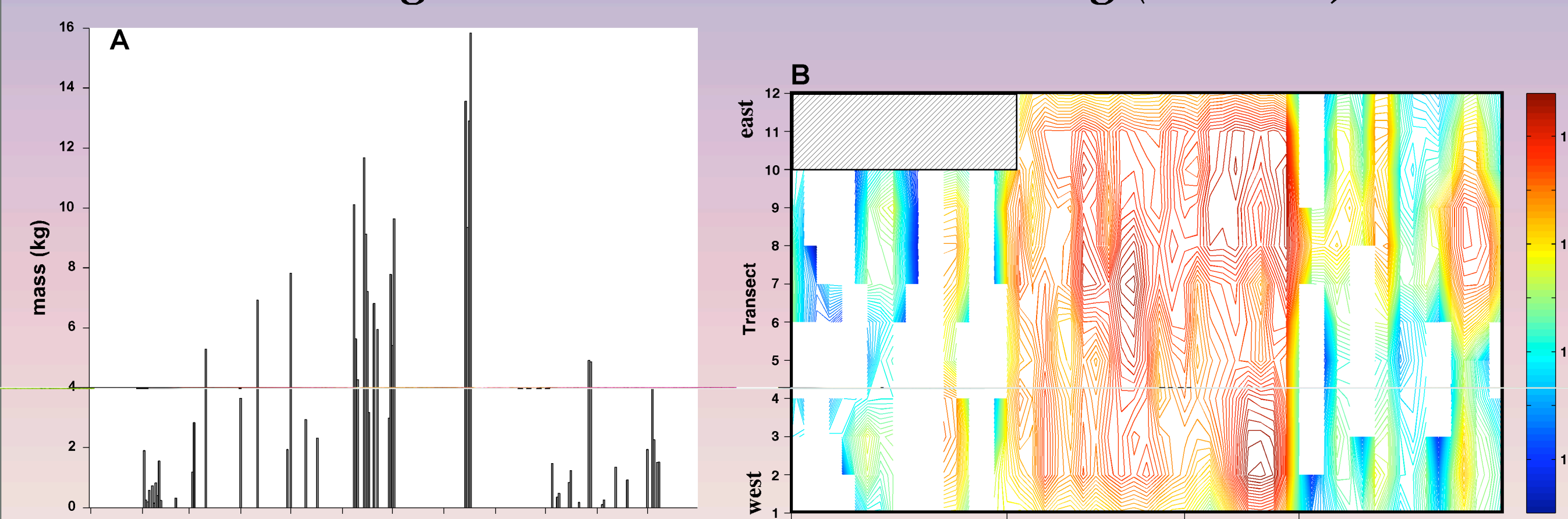
- I) 57 surveys conducted throughout 2005
- II) Survey Area: Coal Oil Point (COP), CA (Figure 3)
- o 12 transects perpendicular to shore around COP (Figure 4-A)
- o Transect observations were interpolated over 19,927 m² survey area
- III) Methodology: Related asphalt accumulation variations to environmental factors
- o Characterized 6 asphalt size classes based on mean diameter (Figure 4-B)
- o Quantified number of asphalts in size classes 1 – 4;
- o Converted into mass using measured mean mass of each size class
- o Quantified number and measured length, width, height of each asphalt in size classes 5 and 6;
- o Converted into mass using measured volumes and density = 1 g/cm³ assumption
- o Collection of Environmental Data (Figure 3-B,C)
- o Wind data at 5 min resolution from Santa Barbara County Air Pollution Control District's West Campus Weather Station (WCS)
- o Swell data at 30 min resolution from University of California, San Diego's Coastal Data Information Program buoy #107
- o Current data at 1 hr resolution from Coastal Ocean Dynamic Application Radar (CODAR) of Interdisciplinary Oceanography Group at University of California, Santa Barbara

Figure 4



4. Results

Figure 5 - Found a seasonal variation in tar accumulation with ten times more tar in spring/summer than fall/winter. Average tar accumulation was 1.6 kg (~3.5 lbs).

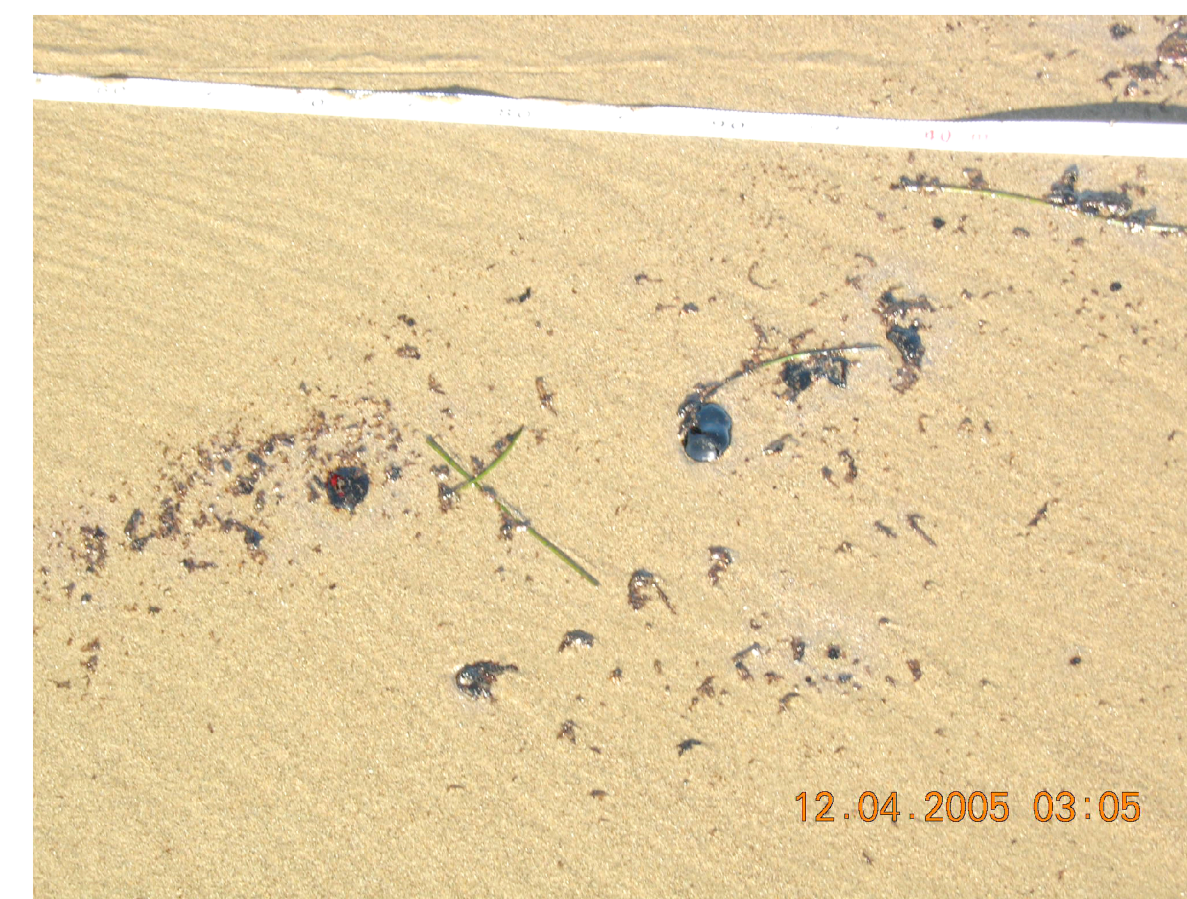


(A) Bar graph showing daily tar accumulation in kilograms throughout 2005. Note that data gaps are no data, not zero tar. (B) Contour plot of asphalt mass per transect per day highlights the seasonal variation with sharp contour boundaries between winter/spring and summer/autumn. White blocks indicate zero tar mass and only occurred during winter and fall. Dashed area indicates no data.

Coastal Oil and Tar Pollution & Natural Marine Hydrocarbon Seeps

The Problem:

Unknown quantities of tar and oil inundate southern California beaches daily via processes that are poorly understood and difficult to model.

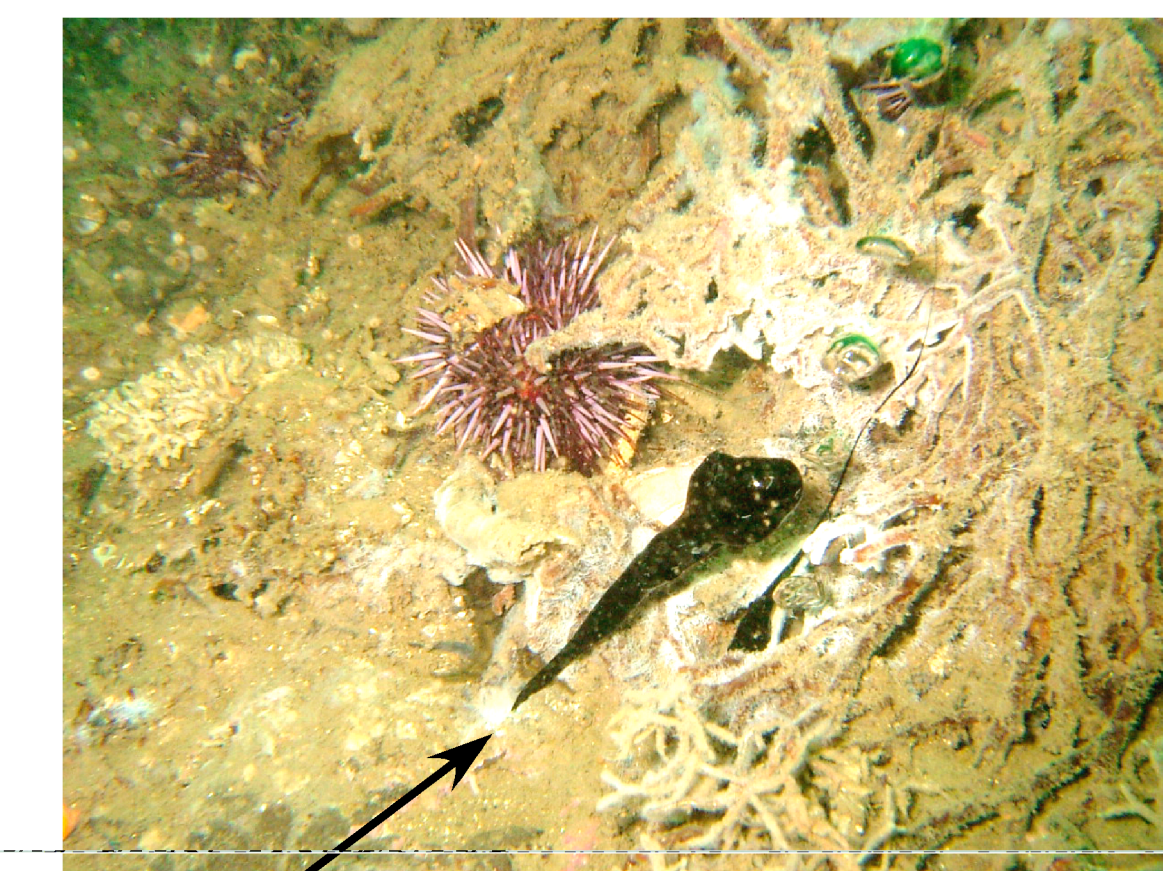


Low Tar Accumulation

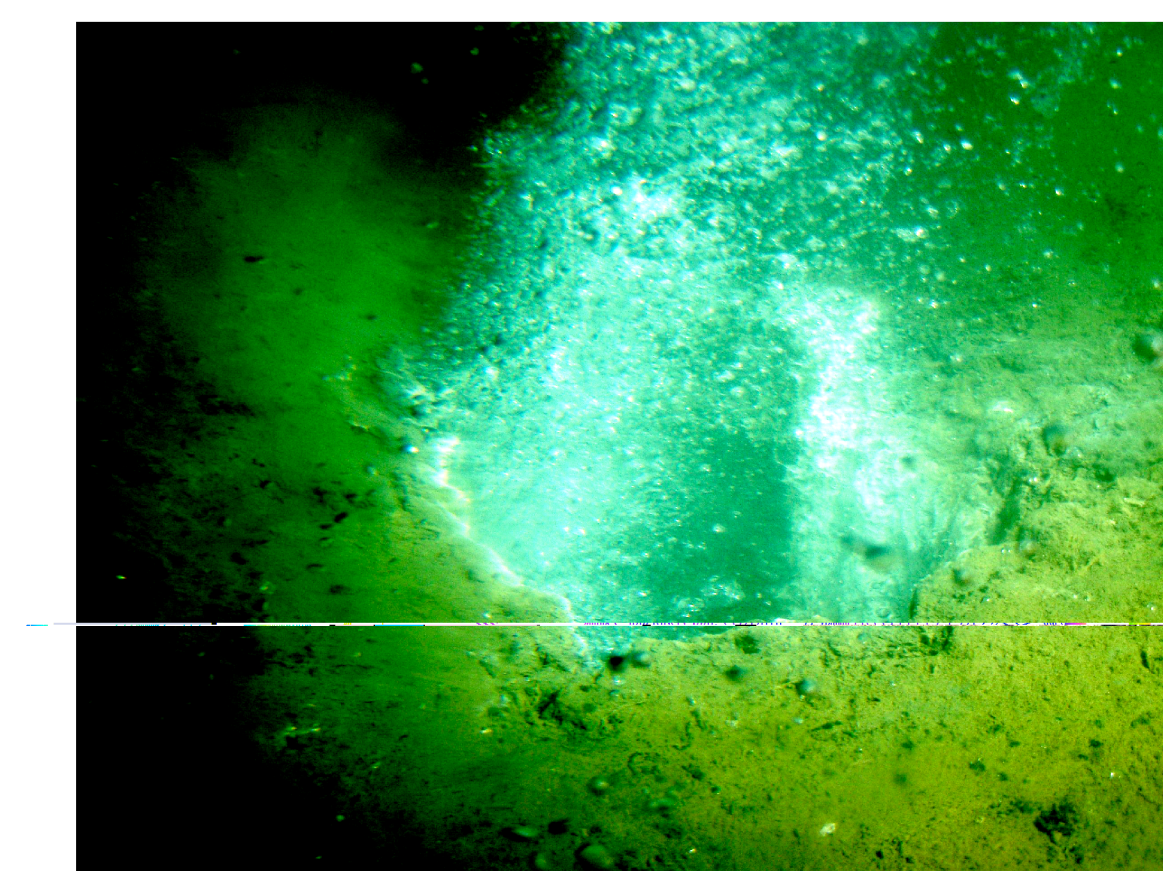


High Tar Accumulation

Oil and asphalt (tar) pollution is a coastal environment concern, particularly for regions with heavy ship traffic and oil production facilities on and offshore, such as coastal southern California. The current knowledge of oil weathering and transport processes, of which oil spill response procedures are based, was gathered largely on laboratory results and less so on actual marine oil spills. The Coal Oil Point (COP) seep field, located within the Santa Barbara Channel offshore of Coal Oil Point, CA, provides a natural laboratory with a constant oil spill source to study spills and the processes affecting them in situ. New knowledge gained from such "real" oil spill studies will improve oil spill response and coastal pollution mitigation procedures.



Oil and Gas Seepage



Gas Seepage

5. Conclusions

1. There was a seasonal variation in tar accumulation with an order of magnitude more tar in the summer than in the winter.
2. Wind is one the most important factors controlling oil slick transport. Light wind is conducive to slick persistence due to a lack of dispersion from breaking waves. Thus, oil slicks remain intact longer giving them more time to reach shore. Onshore breezes help push oil/tar onto the beach.
3. Small swell height is favorable for tar accumulation because it allows slicks to persist and reach shore. Oil slick dispersion is minimal and there is low energy wave-breaking in the surf zone.
4. Swell direction, as well as surface current speed and direction, may play an important role in tar accumulation variations, but further study is needed to isolate their effects.
5. Tidal phase shows no relationship with tar accumulation. High and low accumulations occurred during both flooding and ebbing tides.

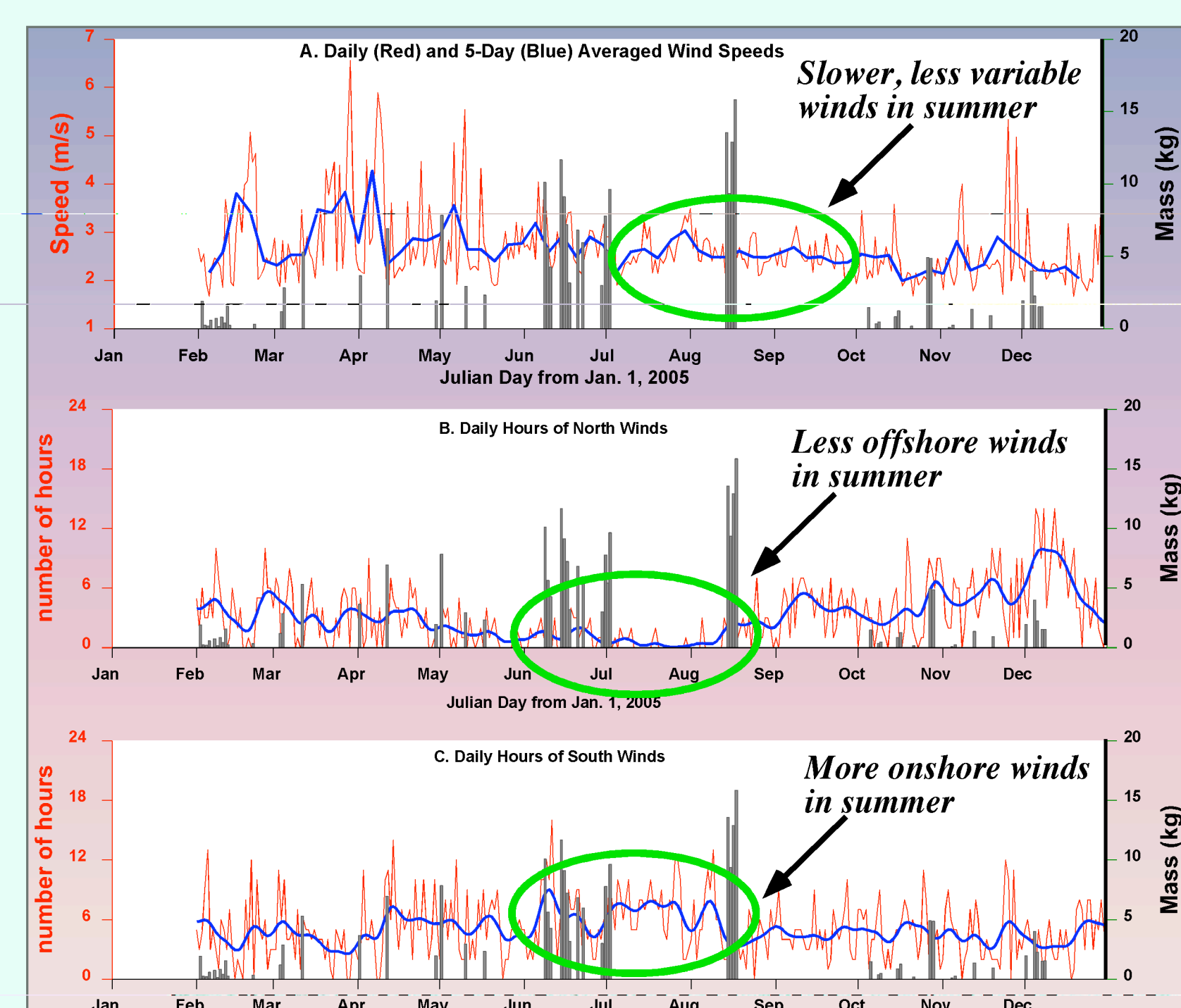
6. Remaining Questions

1. Is the seasonal tar accumulation trend seen in 2005 data an annual occurrence? More yearlong datasets are needed to answer this.
2. How does source variability affect tar accumulation? What factors influence oil emission rates? Seawater temperatures and precipitation rates appear to have a relationship with tar accumulation variations, most likely due to effects on oil emission rates, but further study is needed to model the relationship.

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Figure 6

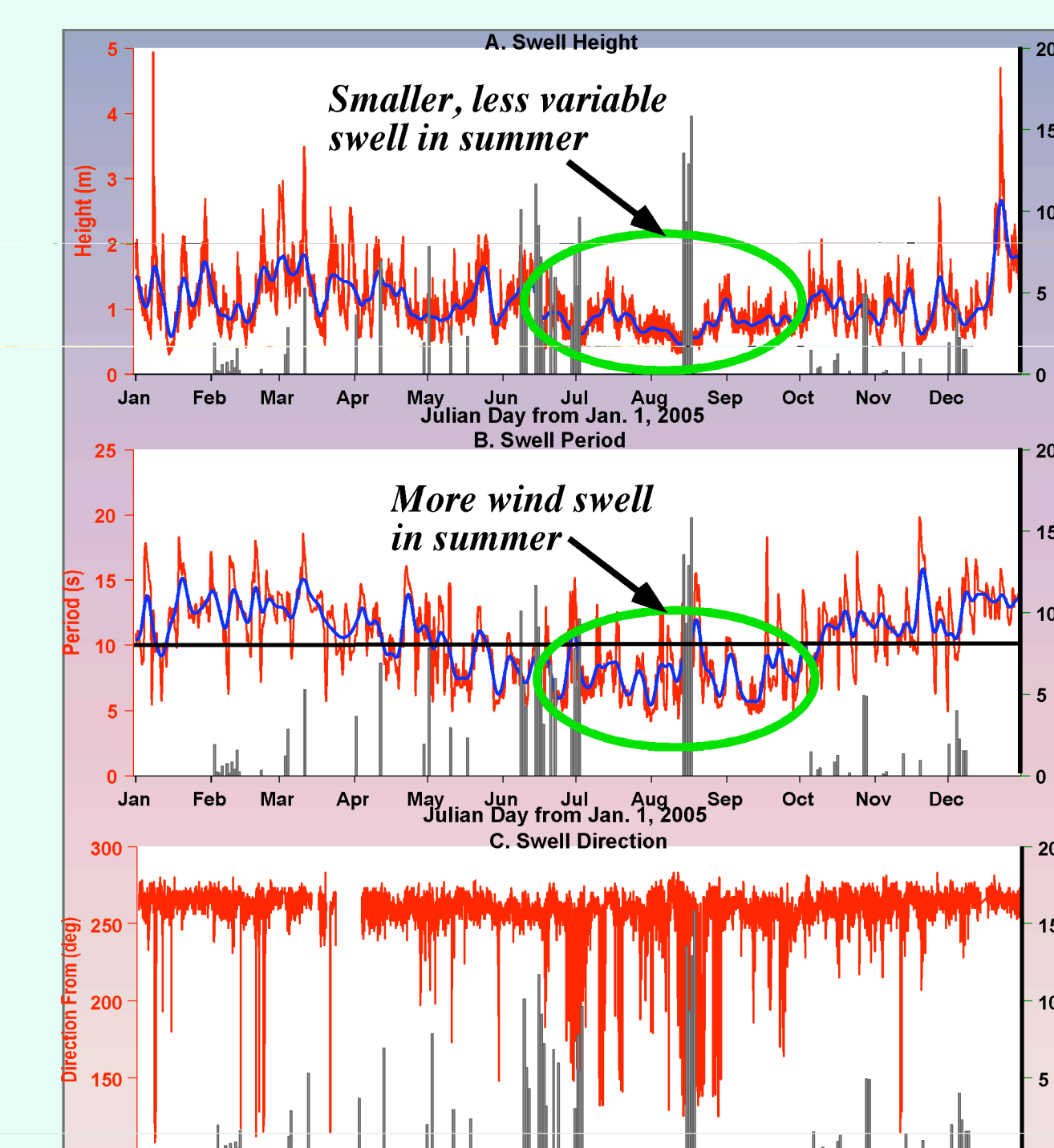
There were slower, less variable winds and more onshore breezes during the summer when tar accumulations were high.



Wind variables are in red and blue and associated with left y-axis. Tar data, shown as bars, are associated with the right y-axis. (A) Averaged wind speeds. (B) Daily hours of North (offshore) winds. (C) Daily hours of South (onshore) winds.

Figure 7

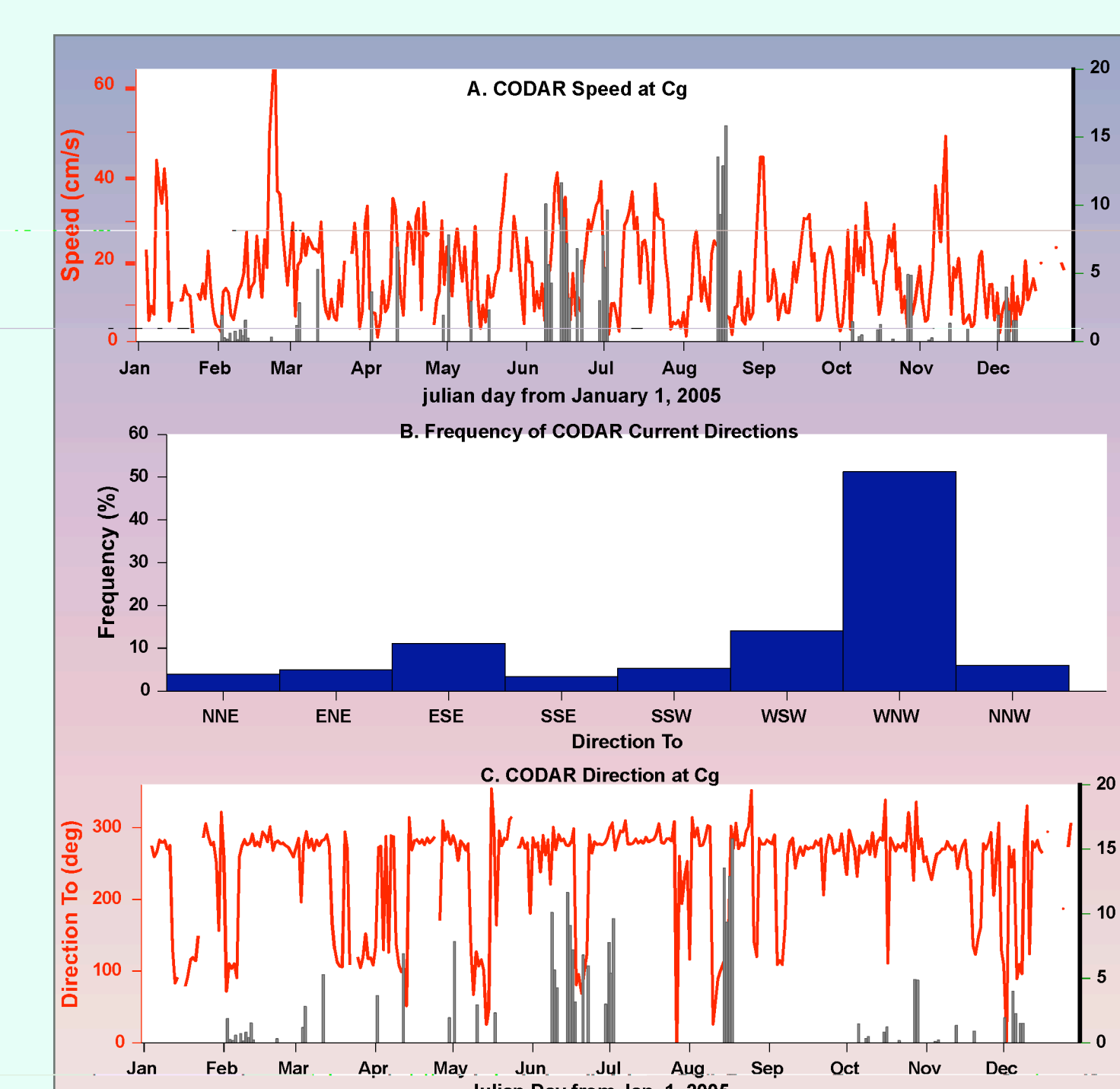
Swell height was smaller and mostly wind-induced during the summer when tar accumulations were high. Swell direction is typically from the west.



Swell variables are in red and blue and associated with left y-axis. Tar data, shown as bars, are associated with the right y-axis. (A) Swell height. (B) Swell period. (C) Swell direction.

Figure 8

Neither surface current speed nor direction showed a seasonal trend comparable to tar accumulation.



Current variables are in red and blue and associated with left y-axis. Tar data, shown as bars, are associated with the right y-axis. Cg is CODAR grid closest to COP. (A) Current speed. (B) Current direction probability. (C) Current direction.